

The Progenitors of Recent Core-Collapse Supernovae

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Abstract. We present the results of our analysis of *Hubble Space Telescope* (*HST*) and deep ground-based images to isolate the massive progenitor stars of the two recent core-collapse supernovae 2008bk and 2008cn. The identification of the progenitors is facilitated in one of these two cases by high-precision astrometry based on our *HST* imaging of SNe at late times.

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SN 2008BK

SN 2008bk is a type II-P supernova, discovered some weeks after explosion [1] in the nearby Scd-type galaxy NGC 7793. The progenitor was first identified in an archival VLT/FORS1 *I*-band image from 2001 September [2]. This identification represents one of the best-resolved known examples of SN progenitors, in the same league as the identification of the star Sk −69 202 in the LMC for SN 1987A. Such examples are quite rare.

We have used IRAF/DAOPHOT PSF-fitting photometry of both Gemini and NOT images. We have scaled the two image sets using stars in the environment of SN 2008bk. For the progenitor star we find $V = 23.80 \pm 0.06$, $R = 22.76 \pm 0.01$, and $I = 21.38 \pm 0.04$ mag. Ground-based observations from Calar Alto/Cafos allowed us to compare the $V - I$ color of SN 2008bk to that of the well-studied SN II-P 1999em, but corrected for $E(V - I)_{\text{tot}} = 0.11$ mag ([3, 4], in order to estimate the color excess for SN 2008bk: $E(V - I)_{\text{tot}} = 0.05 \pm 0.03$ mag. Given that the distance of NGC 7793 is 3.91 ± 0.41 Mpc [5] and the metallicity at the SN site may be subsolar (using the measured metallicity gradient from the host-galaxy center), we confirm that the progenitor of SN 2008bk is a red supergiant (M2), with $T_{\text{eff}} = 3370 \pm 100$ K, $M_{\text{bol}} = -5.90 \pm 0.26$ mag, and $L/L_{\odot} = (1.80 \pm 0.49) \times 10^4$, located in a star cluster. From its position in a Hertzsprung-Russell diagram, our results indicate that, for subsolar metallicity, the SN 2008bk progenitor's initial mass was $8 \pm 1 M_{\odot}$, in agreement with the value estimated by [6] and [7], and with the progenitor masses of other SNe II-P, as systematized by [8] (see [9] for more details).

SN 2008CN

SN 2008cn is a type II-P supernova, discovered a few days past explosion [10] in the spiral galaxy NGC 4603. *HST*/WFPC2 data were taken before and after the SN explosion in F555W ($\sim V$) and F814W ($\sim I$) filters. The pre-explosion observations were obtained between the years 1996 and 1997. The post-explosion target-of-opportunity observations were obtained on 2008 August 26 as part of GO-11119, and the SN was imaged on the PC chip. We geometrically transformed the pre-explosion to post-explosion images to achieve high-precision relative astrometry between the SN and progenitor candidate positions. In two ways we measured the position of the SN and progenitor candidate: DAOFIND and IMEXAM (both within IRAF). Averages from both methods were obtained to adopt a final position.

Photometry of the images was done using HSTphot [11]. The extinction toward the SN was estimated (1) from the equivalent width of the Na I D line at the host-galaxy redshift in a high-resolution SN spectrum and using the relation of [12] ($E(V-I)_{\text{tot}} = 0.44 \pm 0.05$ mag) and (2) comparing our late-time *HST* photometry with the color curve of SN 1999em ($E(V-I)_{\text{tot}} = 0.40 \pm 0.08$ mag). The distance to NGC 4603, 33.3 ± 0.2 Mpc, has been determined using Cepheid variables [13]. Given the position of the SN in the host galaxy we consider solar metallicity.

The precise position of the faint progenitor is challenging, given the proximity of two brighter stars to the candidate which may have affected the determination of the candidate and SN positions. Comparison of the SN/candidate positional difference and the astrometric uncertainties suggests, however, that we have indeed identified the SN progenitor. Considering all previous parameters, we estimate an initial mass for the star $M_{\text{ini}} = 18 \pm 2 M_{\odot}$. This is slightly beyond the initial mass range expected for the red supergiant progenitors of normal SNe II-P, and the star's color is also somewhat more yellow than we would expect. Possibly this is a blend of two (or more) stars, one being brighter and redder, the other being fainter and bluer. If we conclude that the candidate yellow supergiant is not the SN 2008cn progenitor, then the upper limit to the initial mass of any red supergiant progenitor within ~ 5 pixels (~ 80 pc) around the SN position is $M_{\text{ini}} < 14 M_{\odot}$ (see [14] for more details).

REFERENCES

1. L. A. G. Monard, *Central Bureau Electronic Telegrams* **1315** (2008).
2. W. Li et al., *Central Bureau Electronic Telegrams* **1319** (2008).
3. M. Hamuy et al., *Astrophysical Journal* **558**, 615–642 (2001).
4. D. C. Leonard et al., *Publications of the ASP* **114**, 35–64 (2002).
5. T. Lejeune & D. Schaerer, *Astronomy and Astrophysics* **366**, 538–546 (2001).
6. D. Maoz & F. Mannucci, *Astronomer's Telegram* **1464** (2008).
7. S. Mattila et al., *Astrophysical Journal, Letters to the Editor* **688**, 91–94 (2008).
8. S. J. Smartt et al., *Monthly Notices of the Royal Astronomical Society*, submitted (arXiv: 0809.0403).
9. S. D. Van Dyk et al., in preparation (2009).
10. R. Martin & L. A. G. Monard, *Central Bureau Electronic Telegrams* **1385** (2008).
11. A. E. Dolphin, *Publications of the ASP* **112**, 1383–1396 (2000).
12. N. Elias-Rosa, in preparation (2009b).
13. J. A. Newman, et al., *Astrophysical Journal* **523**, 506–520 (1999).
14. N. Elias-Rosa, in preparation (2009a).